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IMPACT OF IN-CHANNEL ORGANIC DEBRIS ON CHANNEL GEOMORPHOLOGY AND IN-CHANNEL STRUCTURES

Second Quarterly Report to the US Army Corps of Engineers

OCTOBER 1995

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Administrative Developments

Mr Wallerstein has transferred registration from MPhil to PhD status at the University of Nottingham. Mr P. Cheesman has successfully completed the five month sub-contract to develop a GIS front end to the debris management support system.

Logistics and Travel

In a separate but related US Army Corps of Engineers contract Mr Wallerstein is to spend ten days (11th and 21st October 1995) visiting three hydraulics research institutes in Europe to gather primary and secondary information about floating woody debris management at run-of-the-river structures to be compiled into a comprehensive literature survey.

Research Progress

Over the last three months efforts have been concentrated on refining the C++ program and GIS database. The Abiaca Creek GIS database has been integrated with the debris management support program and the system is now fully operational. A conference paper discussing the development of this debris management support system has been submitted for the Sixth Federal Interagency Sedimentation Conference. The paper is included with this report, see Appendix B.

Data Analysis

Survey results from the May 1995 field visit have been collated and entered into the data-base. Figure 1 shows the qualitative and quantitative variables for each debris jam site. Figure 2 shows the debris input sources for each creek and site. The main input mechanisms appear to be through outer-bank erosion in active meanders and through bank failure in unstable reaches.

Appendix A shows the results of the debris at bridge pier survey which was carried out during the May 1995. The data from this survey has been used to test Melville and Dongol's pier scour model which has been incorporated into the Wallerstein Debris Management Program. Pages 5 to 13 show the input variables and results for each bridge site. A summary table is given on page 13 along with a plot of the results (Figure 3). In figure 3 the diagonal line represents a perfect match between actual measured scour depths and those predicted by the model. It is evident that the majority of the predicted values are greater than those observed. This discrepancy may be explained however by the fact that scour observations were made during low flow conditions when the scour holes depths were likely to have been less than those under bankfull conditions (bankfull values were used in the model), due to sediment deposition during receding flows.

Plans for the next quarter

- Conduct European research trip for related US Army Corps of Enginners contract.
- Continue analysis of survey and geomorphic data from summer 1995 field visit.
- Submit sub-contract final report for the GIS debris management support system.
- Arrange January 1996 data collection field trip.

Figure 1 : Debris input source areas : May 1995

Creek	Site	No. Jams	Vol. jams (m^3)	Flow Direction	Influence	Alpha Angle	Beta Angle	Sinuosity	knickzone	sediment	Bar deposition (m^3)	Backwater Deposition (m^3	Bed Scour (m^3)
Abiaca 3	1		8.83	dam	partial	90	0	slightly sinuous	no	sand		1x5x0.5	
	2		0.75	dam	partial	100	0	slightly sinuous	no	sand	2x10x0.5		0. 5x2x2
	3		6.36	dam	partial	90	0-20	slightly sinuous	no	sand		minor	minor
	4		13.15	dam/deflector	partial	90-130	0	sinuous	no	sand	7x12x2		10x1x1
	5		8.48	deflector	partial	90	10	meandering	no	sand	12x6x0.5	8x10x0.5	8x3x1
	6	6	3.39	dam	active	90	0	meandering	no	sand	point bar	minor	
			Total 40.96										
											Total sedimentation 254 ptf 63.3		Total scour 36 ptf 9
Fannegusha	1		5.65	dam	complete	90	0	straight	no	sand			
	2		31.42	dam-underflow	partial	90	0	straight	yes	sand	10x6x0.5		30x10x1
	3	3	3.14	dam	partial	90	0	straight	yes	sand	10x10x1		
			Total 40.21										
											Total sedimentation 130 ptf 32.5		Total scour 300 ptf 75
Harland 1	1		13.42	deflector	complete	90-180	0	slightly sinuous	no	sand/gravel	10x6x2	20x10x0.5	5x5x1
	2		8.83	parallel	partial	180	0	slightly sinuous	no	sand/gravel	15x5x0.5		20x10x3
	3		8.47	parallel	partial	180	0	meandering	no	sand/gravel	5x10x1		20x10x2
	4		14.12	parallel	complete	90	0	meandering	no	sand/gravel	minor		30x5x3
	5		10.37	parallel	partial	180	0	meandering	no	sand/gravel	25x5x1.5	15x8x0.5	
	6		3.77	parallel	partial	180	0	meandering	no	sand/gravel			40x6x1
	7		9.08	dam	complete	90	0	meandering	no	sand/gravel		10x5x0.5	5x3x1
	8	8	5.29	parallel	partial	180	0	meandering	no	sand/gravel	minor		1x0.5x0.5
			Total 73.35										
											Total sedimentation 580 ptf 128.9		Total scour 1730 ptf 38
Abiaca 4	1		3.45	parallel	partial	180	0-30	meandering	no	sand/gravel			outer bank
	2	2	21.01	deflector-parallel	complete	90-180	0	meandering	no	sand/gravel	10x5x1	20x8x0.5	40x10x0.5
			Total 24.46										
											Total sedimentation 130 ptf 32.5		Total scour 200 ptf 50
Otoucalofa	no sites surveyed		Total 27.48										
Long	1	1	19.63	dam-underflow	partial	90	0	meandering	yes	sand			
	rest of reach		127.28										
			Total 146.91								Total 0		Total 0
Lee	1		1.41	deflector	partial	90	0	straight	no	sand	minor		
	2		2.82	dam	partial	90	0	straight	no	sand			
	3	3	1.41	dam-underflow	partial	90	0	straight	no	sand		15x6x0.2	10x5x0.5
			Total 5.64								Total sedimentation 18 ptf 4.5		Total scour 25 ptf 6.25
Hickahala	1		27.29	dam	active	90	0	straight	no	sand/clay bed	15x5x0.5		
	2	2	47.11	dam	complete	90	0	straight	yes	sand/clay bed		15x8x0.5	
			Total 74.4										
											Total sedimentation 97.5 ptf 21.67		Total scour 0
Harland 23	1		12.71	parallel	partial	180	0	meandering	no	sand			
	2	2	15.08	deflector	partial	110	0	meandering	no	sand			
	rest of reach		142.33										
			Total 170.12										
											Total 0		Total o
Nolehoe	1		5.66	underflow	partial	90-180	30	straight	yes	sand/gravel			
	2-3		22.63	deflector	partial	100	20	straight	yes	sand/gravel/clay		10x6x0.3	10x5x0.5
	4-5		13.2	deflector	partial	130	20	straight	yes	sand/gravel		10x5x0.5	
	6		10.06	underflow	partial	90	20	straight	yes	sand/gravel	15x5x0.5		
	7		16.97	deflector	partial	90-180	20-30	straight	yes	sand/silt/gravel			
	8	8	12.57	deflector	partial	90	10	straight	yes	sand/silt/gravel	0.5x10x5		
			Total 81.09										
											Total sedimentation 105.5 ptf 26.38		Total scour 25 6.25
Lick	1		11.31	deflector	partial	90	0	straight	yes	clay/gravel	15x10x1		minor
			Total 11.31										
											Total sedimentation 180 ptf 45		Total scour 0
Perry	1		2.82	underflow	partial	90	0	sinuous	no	sand			
	2		5.03	underflow	partial	90	0	sinuous	no	sand/gravel			
	3		10.06	dam	complete	180	0	sinuous	no				
	4		7.06	dam	partial	90	0	sinuous	no	sand			
	5		7.06	dam	complete	90-180	0	slightly sinuous	no	sand			
	6		5.03	underflow	partial	90	0	meandering	no	sand			
	7	7	4.24	underflow	partial	90	0	sinuous	no	sand			
	rest of reach		20.27										
			Total 61.57										
											Total sedimentation 0		Total scour 0
Abiaca 6	1	bridge											
	2	2	2.51	parallel	partial	180	0	straight	no	sand/gravel	30x10x0.2		
			Total 2.51										
											Total sedimentation 60 ptf 13.33		Total scour 0
Coila	1		1.41	underflow	partial	90	0	straight	no	sand/gravel	15x4x0.5		
	2		3.93	underflow	partial	90	0	meandering	no	sand/gravel			
	3		1.06	parallel	partial	180	0	slightly sinuous	no	sand/gravel			
	4		4.94	parallel	partial	180	0	slightly sinuous	no	sand/gravel			
	5		5.65	parallel	partial	180	0	meandering	no	sand/gravel	25x10x1		
	6		24.89	parallel	partial	180	0	meandering	no	sand/gravel	point bar		
	7	7	1.57	parallel	partial	180	0	meandering	no	sand/gravel	30x10x1		15x5x1
			Total 43.45										
											Total sedimentation 580 ptf 145		Total scour 65 ptf 16.2
Sykes	1		1.57	deflector	partial	90-180	0	meandering	no	sand	scour at piers		
	2		18.84	deflector	partial	180	0	meandering	no	sand/clay	point bar		
	3		12.57	dam-underflow	partial	180	0	meandering	no	sand	10x5x0.5		
	4	4	11.63	parallel	partial	180	0	meandering	no	sand	30x10x1.5		
			Total 44.61										
											Total sedimentation 475 ptf 118.75		Total scour 0
Worsham west	1		5.66	dam-underflow	partial	90	5	sinuous	no	sand	10x5x0.3		
	2		0.47	underflow	partial	90	0	sinuous	no	sand			
	3		2.12	dam-underflow	partial	90	0	sinuous	no	sand		10x5x0.5	2x2x0.3
	4		7.54	dam-underflow	partial	90	0	slightly sinuous	no	sand			0.6x3x2
	5		1.96	dam	partial	90	0	slightly sinuous	no	sand			
	6		5.66	dam-underflow	partial	90	0	sinuous	no	sand	5x4x0.5	minor	
	7		6.35	daflector	partial	100	0	sinuous	yes	sand	point bar		2x2x1
	8		12.57	dam-underflow	partial	90	0	slightly sinuous	yes	sand	15x15x0.5		
	9	9	12.57	deflector	complete	90	0	sinuous	yes	sand	8x5x0.5		
			Total 54.9										
											Total sedimentation 182.5 ptf 19.2		Total scour 8.8 ptf 0.93

Figure 2 : LWD survey results, May 1995

		Input mechanism at jam					
creek	site	death	beaver activity	windthrow	channel instability	active meandering	floated from upstream
Abiaca 3	1				o		
	2					o	
	3					o	
	4					o	
	5					o	
	6					o	
Fannegusha	1						o
	2				o		
	3				o		
Harland 1	1				o		
	2				o		
	3						o
	4					o	
	5					o	
	6					o	
	7				o		
	8					o	
Abiaca 4	1						o
	2					o	
Otoucalofa	debris on outside of most bends - failed and floated						
Lee	1			o			
	2			o			
	3			o			
Nolehoe	1				o		
	2-3				o		
	4-5				o		
	6				o		
	7				o		
	8				o		
Lick	1				o		
Perry	1					o	
	2			o			
	3				o		
	4				o		
	5				o		
	6					o	
	7					o	
Abiaca 6	1						o
	2			o			
Coila	1			o			
	2			o			
	3			o			
	4					o	
	5					o	
	6					o	o
	7					o	o
Sykes	1						o
	2					o	
	3					o	
	4					o	
Worsham W	1				o		
	2					o	
	3			o			
	4				o		
	5		oooo				
	6					o	
	7					o	
	8				o		
	9				o		
Harland 23	1						o
	2				o		
	other					oooooooo	
Long	1				o		
TOTAL		0	4	8	22	31	8
TOTAL %		0	6	10	30	43	11

APPENDIX A

SCOUR AT BRIDGE PIERS : DATA FROM DEC CREEK : MAY 1995

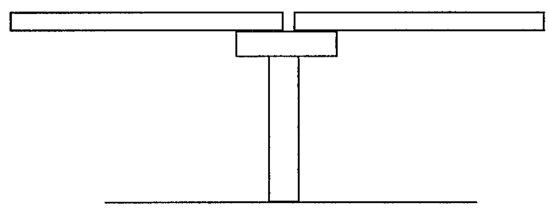
1) Creek location : Abiaca 21 Highway 49E

Pier diameter : 1.5 m
Pier construction : circular piers, concrete
Angle of flow approach : 90
Pier spacing : parallel to flow:
90 degrees to flow :
Channel width: regime : 48.34m
Flow depth : regime : 3.01m
Scour depth at pier :
Bed material : sand

Debris dimensions :	width (90 deg to flow)	: no debris build-up
	length (parallel to flow)	
	depth	:

Diagram :

90 degrees to flow



2) Creek location : Abiaca 3, bridge at 2000ft survey

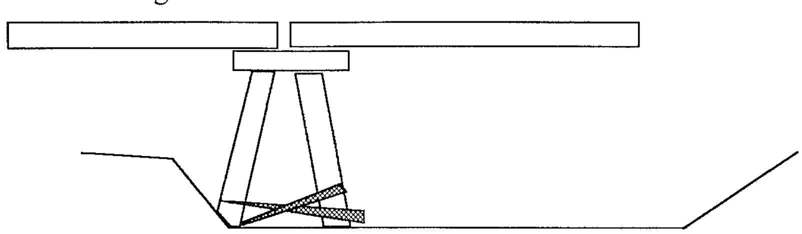
Pier diameter : 0.5 m
Pier construction : square, concrete

Angle of flow approach : 90
Pier spacing : parallel to flow:
90 degrees to flow :
Channel width: regime : 26.33m
Flow depth : regime : 2.51m
Scour depth at pier : 0.3m
Bed material : sand

Debris dimensions :	width (90 deg to flow)	: 2m
	length (parallel to flow)	: 1m
	depth	: 0.3m

Diagram :

90 degrees to flow



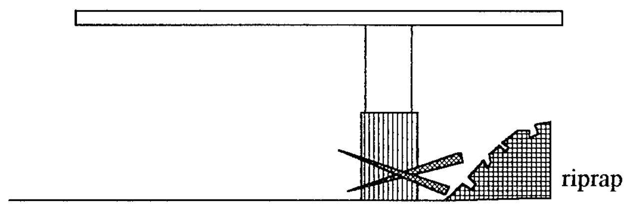
3) Creek location : Harland 1, country road bridge at 2000ft survey

Pier diameter : 0.55m
Pier construction : steel shell surrounding concrete, bottom two metres are circular, above is square
Angle of flow approach : 90
Pier spacing : parallel to flow: 4 equally spaced piers
90 degrees to flow :
Channel width: 11.25m : regime : 21.59m
Flow depth : 0.46m : regime : 2.09m
Scour depth at pier : 0.46m
Bed material : sand

Debris dimensions :	width (90 deg to flow)	: 2m
	length (parallel to flow)	: 10m / 4 piers = 1.2m
	depth	: 0.5m

Diagram :

90 degrees to flow



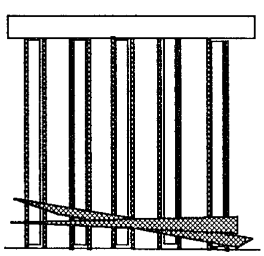
4) Creek location : Abiaca 6, bridge at 0ft survey

Pier diameter : 0.24m
Pier construction : I beam girders, 5 equally spaced beams in each pier
Angle of flow approach :
Pier spacing : parallel to flow: 1.92m
90 degrees to flow : 5.5m
Channel width: 19.8m : regime : 28.7m
Flow depth : 0.3m : regime : 2.09m
Scour depth at pier : 0.61m
Bed material : sand

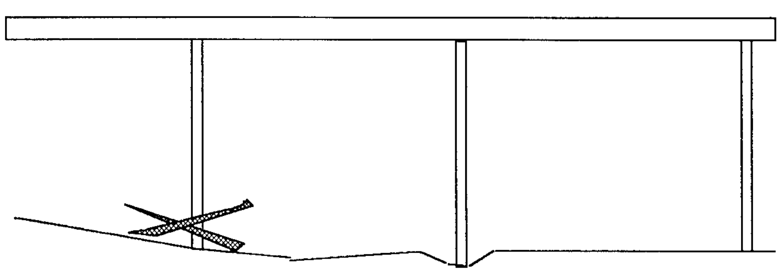
Debris dimensions :	width (90 deg to flow)	: 4.8m
	length (parallel to flow)	: 7.6m / 5 piers = 1.52m
	depth	: 1.22m

Diagram :

parallel to flow



90 degrees to flow



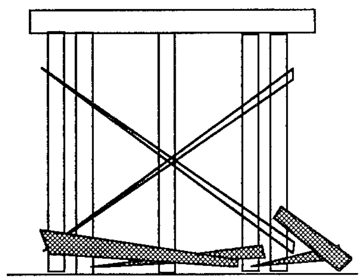
5) Creek location : Fannegusha, bridge at 2000ft survey

Pier diameter : 0.3m
Pier construction : wooden, circular
Angle of flow approach : 90
Pier spacing : parallel to flow: 1.06m
90 degrees to flow : 4.26m
Channel width: regime : 13.41m
Flow depth : regime : 2.10m
Scour depth at pier : 0m
Bed material : sand

Debris dimensions :	width (90 deg to flow)	: 17.94 / 2 = 9m
	length (parallel to flow)	: 2.7m
	depth	:1.8m

Diagram :

parallel to flow



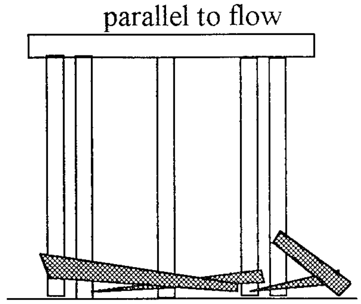
6) Creek location : Sykes, bridge at 2000ft survey

Pier diameter : 0.3m
Pier construction : wooden, circular. bridge being collapsed by pressure force on debris
Angle of flow approach : 90
Pier spacing : parallel to flow: 1.82m
90 degrees to flow : 7.30m
Channel width: regime : 23.2m
Flow depth : 1.82m
Scour depth at pier : 1m
Bed material : sand

Debris dimensions :	width (90 deg to flow)	: 5.1m
	length (parallel to flow)	: 2.7m
	depth	: 3m

Diagram :

parallel to flow



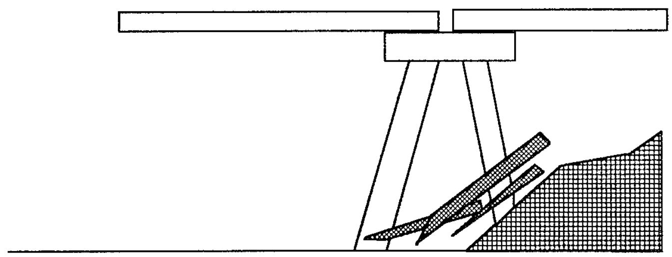
7) Creek location : Harland 23, bridge at 0ft survey

Pier diameter : 0.3m
Pier construction : square, concrete
Angle of flow approach : 90
Pier spacing : parallel to flow : 1.5m
90 degrees to flow : 30m
Channel width:
Flow depth :
Scour depth at pier :
Bed material : sand

Debris dimensions :		
	width (90 deg to flow)	: 2.4m
	length (parallel to flow)	: 6m / 4 piers = 1.5m
	depth	: 1.8m

Diagram :

90 degrees to flow



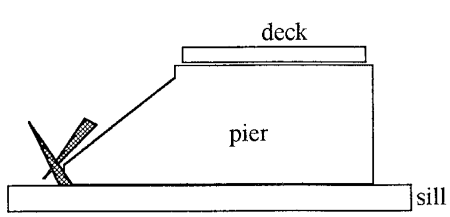
8) Creek location : Nolehoe, bridge at 0ft survey

Pier diameter : 0.6ft (90 degrees to flow)
Pier construction : box culvert
Angle of flow approach : 80
Pier spacing : parallel to flow :
90 degrees to flow : 4.26m
Channel width: regime : 10.64m
Flow depth : regime : 1.28m
Scour depth at pier :
Bed material : clay

Debris dimensions :		
	width (90 deg to flow)	: minor debris on pier face
	length (parallel to flow)	
	depth	:

Diagram :

parallel to flow



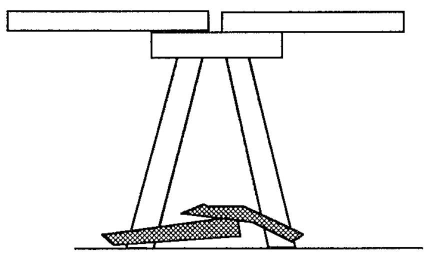
9) Creek location : Redbanks, bridge at 0ft survey

Pier diameter : 0.3m
Pier construction : I beam girders : flow approach is --> I to I
Angle of flow approach : 80
Pier spacing : parallel to flow:
90 degrees to flow :
Channel width: regime : 40.13m
Flow depth : regime : 2.65m
Scour depth at pier : 0.5
Bed material : sand

Debris dimensions :		
	width (90 deg to flow)	: 3m
	length (parallel to flow)	: 1.8m
	depth	: 1m

Diagram :

90 degrees to flow direction : 4 sets of A pilings in each pier



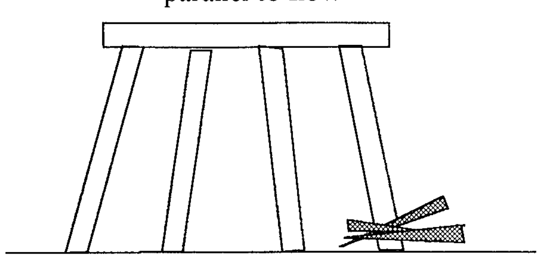
10) Creek location : Burney Branch, bridge at 1000ft

Pier diameter : 0.3m
Pier construction : square, concrete
Angle of flow approach : 90
Pier spacing : parallel to flow : 2.13m
90 degrees to flow :
Channel width: regime : 32.92m
Flow depth : regime : 2.31m
Scour depth at pier : 0.43m
Bed material : sand

Debris dimensions :		
	width (90 deg to flow)	: 2m
	length (parallel to flow)	: 2m
	depth	: 1m

Diagram :

parallel to flow



PIER SCOUR PREDICTION MODEL RESULTS

1) Abiaca 3, bridge at 2000ft survey

Pier diameter : D 0.5 metres
Approach flow depth : Y 2.51 metres
Debris raft length parallel to flow : Dd 1 metres
Debris raft depth : Td 0.3 metres
Debris raft width perpendicular to flow : Dw 2 metres
channel width : w 26.33 metres

Bed Scour Due to pier (ds) = 1.2 metres

Bed scour due to pier and debris accumulation (dsd) = 1.27 metres

Increase in approach water depth at the bridge (Yd) = 0.03 metres

New total approach water depth (Y+Yd) = 2.54 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 441.45 N/m width.

2) Harland 1, country road bridge at 2000ft survey

Pier diameter : D 0.55 metres
Approach flow depth : Y 2.09 metres
Debris raft length parallel to flow : Dd 1.2 metres
Debris raft depth : Td 0.5 metres
Debris raft width perpendicular to flow : Dw 2 metres
channel width : w 21.59 metres

Bed Scour Due to pier (ds) = 1.32 metres

Bed scour due to pier and debris accumulation (dsd) = 1.51 metres

Increase in approach water depth at the bridge (Yd) = 0.05 metres

New total approach water depth (Y+Yd) = 2.14 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 1.23e+03 N/m width.

3) Abiaca 6, bridge at 0ft survey

Pier diameter : D 0.24 metres
Approach flow depth : Y 2.09 metres

Debris raft length parallel to flow : Dd 1.52 metres
Debris raft depth : Td 1.22 metres
Debris raft width perpendicular to flow : Dw 4.8 metres
channel width : w 28.7 metres

Bed Scour Due to pier (ds) = 0.58 metres

Bed scour due to pier and debris accumulation (dsd) = 1.51 metres

Increase in approach water depth at the bridge (Yd) = 0.08 metres

New total approach water depth (Y+Yd) = 2.17 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 7.3e+03 N/m width.

4) Fannegusha, bridge at 2000ft survey

Pier diameter : D 0.3 metres
Approach flow depth : Y 2.1 metres
Debris raft length parallel to flow : Dd 2.7 metres
Debris raft depth : Td 1.8 metres
Debris raft width perpendicular to flow : Dw 9 metres
channel width : w 13.41 metres

Bed Scour Due to pier (ds) = 0.72 metres

Bed scour due to pier and debris accumulation (dsd) = 3.29 metres

Increase in approach water depth at the bridge (Yd) = 0.3 metres

New total approach water depth (Y+Yd) = 2.4 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 1.58e+04 N/m width.

5) Sykes, bridge at 2000ft survey

Pier diameter : D 0.3 metres
Approach flow depth : Y 1.82 metres
Debris raft length parallel to flow : Dd 2.7 metres
Debris raft depth : Td 3 metres
Debris raft width perpendicular to flow : Dw 5.1 metres
channel width : w 23.2 metres

Bed Scour Due to pier (ds) = 0.72 metres

Bed scour due to pier and debris accumulation (dsd) = 5.66 metres

Increase in approach water depth at the bridge (Yd) = 0.17 metres

New total approach water depth (Y+Yd) = 1.99 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 4.41e+04 N/m width.

6) Redbanks, bridge at 0ft survey

Pier diameter : D 0.3 metres
Approach flow depth : Y 2.65 metres
Debris raft length parallel to flow : Dd 1.8 metres
Debris raft depth : Td 1 metres
Debris raft width perpendicular to flow : Dw 3 metres
channel width : w 40.13 metres

Bed Scour Due to pier (ds) = 0.72 metres

Bed scour due to pier and debris accumulation (dsd) = 1.43 metres

Increase in approach water depth at the bridge (Yd) = 0.04 metres

New total approach water depth (Y+Yd) = 2.69 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 4.91e+03 N/m width.

7) Burney Branch, bridge at 1000ft survey

Pier diameter : D 0.3 metres
Approach flow depth : Y 2.31 metres
Debris raft length parallel to flow : Dd 2 metres
Debris raft depth : Td 1 metres
Debris raft width perpendicular to flow : Dw 2 metres
channel width : w 32.92 metres

Bed Scour Due to pier (ds) = 0.72 metres

Bed scour due to pier and debris accumulation (dsd) = 1.64 metres

Increase in approach water depth at the bridge (Yd) = 0.04 metres

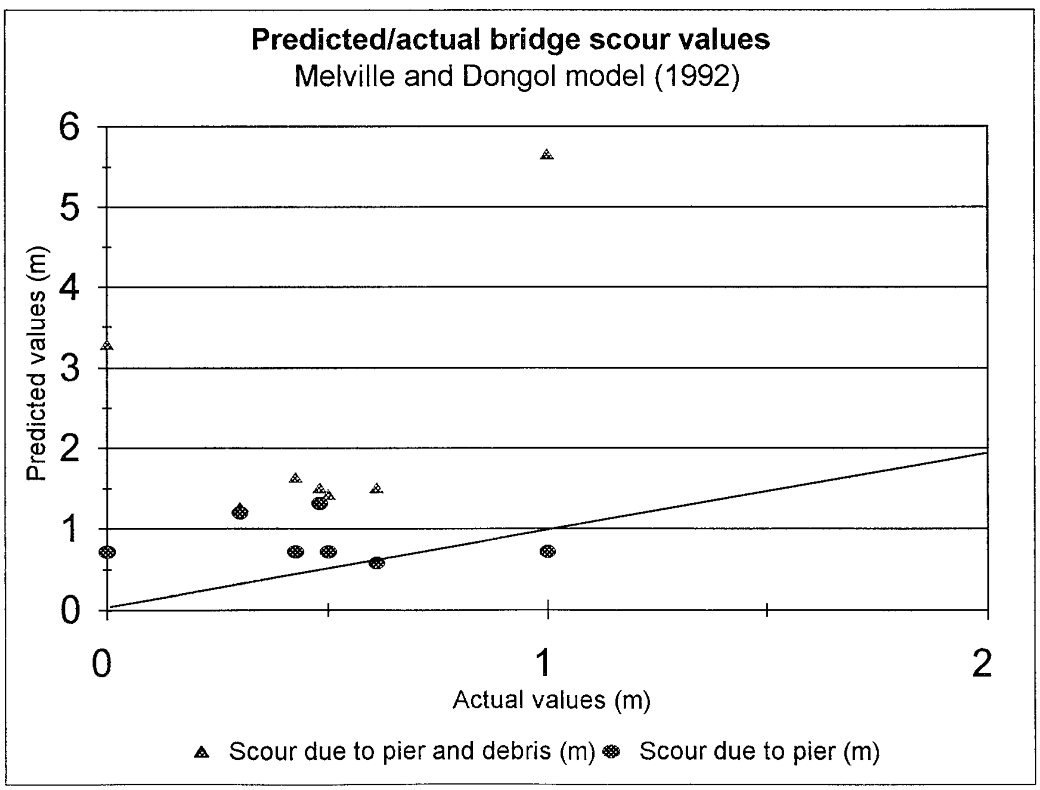
New total approach water depth (Y+Yd) = 2.35 metres

Pressure Force on the bridge pier at the centre of the debris raft (Pf) = 4.91e+03 N/m width.

Summary table

creek	predicted pier scour	predicted pier & debris scour	actual scour
Abiaca 3	1.2	1.27	0.3
Harland 1	1.32	1.51	0.48
Abiaca 6	0.58	1.51	0.61
Fannegusha	0.72	3.29	0
Sykes	0.72	5.66	1
Redbanks	0.72	1.43	0.5
Burney Branch	0.72	1.64	0.425

Figure 3



APPENDIX B

IMPACT OF IN-CHANNEL ORGANIC DEBRIS ON FLUVIAL PROCESS AND CHANNEL FORM IN UNSTABLE CHANNEL ENVIRONMENTS

Abstract In this paper, degrading, unstable channels in northern Mississippi are examined to assess whether the input of Large Woody Debris (LWD) and formation of debris jams is significant in terms of channel stability management. US Army Corps of Engineers Demonstration Erosion Control data-sets have been utilised to identify significant debris-jams in planform and long profile at 23 river reaches so that changes in debris input volume, jam stability and the associated scour, backwater sedimentation and bank erosion/ accretion can be monitored through time.

Results indicate that the impact of debris jams varies primarily with jam orientation relative to the main flow direction. Impacts change from depth adjustment through bed scouring in small creeks, to width adjustment through lateral erosion in medium size streams, to negligible effects in the largest creeks. Processes, therefore, appear to be watershed-scale dependent and evidence suggests that the ratio of average riparian tree height to channel width can be used as an indicator of the likely impact that a jam will have on channel morphology and sediment routing.

The relationships between LWD formations and channel processes have been incorporated into a Drainage Basin Debris Management computer program, written in C++. Input data take the form of those variables found to be significant in terms of debris-channel interactions including channel width functions, average tree height/species parameters and sediment type. The output data given is based upon the relationships found in the current research and consists of recommendations, with explanatory notes, for debris removal, retention, relocation or input depending on the type of management strategy desired in a particular catchment or channel reach.

INTRODUCTION

Numerous papers have been written on the subject of Large Woody Debris (LWD) concerning input processes, spatial location within the channel network, and impact upon channel morphology, flow and sediment routing. The majority of studies have, however, been carried out in stable gravel-bed rivers, especially in isolated headwater reaches, although one or two studies, such as that by Gregory, Davis and Tooth (1993), have dealt with watershed-wide processes. Consequently management issues have only been addressed in headwater environments. The aim of this research is to obtain a better understanding of the watershed-wide impact of debris jams in stable and unstable channel environments. This is important because debris management is currently carried out using engineers' judgement on an *ad hoc* basis. For a coherent basin-wide debris management strategy decision makers need to know how important debris jams are in terms of inhibiting or promoting bed and bank scour, sediment transport and deposition. Prediction of debris build-up rates at run-of-the-river structures is also vitally important for correct operations and maintenance procedures. Debris can, for example, be a major problem at bridges where it can cause excessive pier scour, localised flooding and increase the pressure force on piers. Parola et al.

(1994) investigated bridge failures after the 1993 Mississippi River Basin flood and found that debris induced lateral loading and scour and was a contributing factor to many of the failures. Debris can also cause maintenance problems at other structures such as locks, dams and weirs where, for instance, sluice gates can become jammed open and the hydraulic capacity of spillways and conduits can be impaired. Large debris can also be a hazard to navigation.

ANALYSIS

Method The study area is in the US Army Corps of Engineers Demonstration Erosion Control watersheds in the Yazoo Basin, northern Mississippi. Twenty-three channel reaches, from 4000 to 12000 feet long, with a range of watershed area of between 3 and 150 square miles have been surveyed. The reaches fall into several categories which are being compared with respect to LWD dynamics. These categories include stable/unstable reaches, straight/meandering reaches and reaches which have either a predominantly agricultural or wooded riparian strip. Thalwegs and cross-sections are surveyed through each reach once every 6 months. Debris jams in each reach are surveyed with the thalweg data to monitor their stability and the changes in associated bed scour and sedimentation. The survey data is plotted in graphical form and subsequent data-sets overlaid so that changes in debris jam position and thalweg topography are apparent.

Survey Results From field observations it is apparent that the main LWD input mechanism in these channels is tree topple due to bank failure. Also, in November 1993, over the period of one or two days, a heavy frost caused branches to tear off a large number of trees in the northern half on the DEC survey area causing a sudden influx of new debris material into many catchments. It appears, however, that because much of this load is composed of only limbs, rather than whole trees, it has been moved by high flows to previously established debris jams, rather than forming new sites of obstruction.

On a catchment-wide scale it is evident that major debris input regions and jam concentrations are to be found in laterally unstable reaches, especially downstream of knickpoints and knickzones. It is also apparent that the input of debris from the outside of actively migrating meander bends from both stable and unstable channels is significant as a large proportion of the total number of jams surveyed can be found at the apex of bends, while significant debris input in straight channels is limited to those reaches which are highly unstable. Meander apexes are also a preferential site for deposition of debris which has been floated from upstream. This is likely to be due to the propelling of debris to the outside of bends by centrifugal force and outward flowing secondary currents at the water surface. During high flow events debris then becomes snagged in vegetation or is pinned to the bank and deposited at its base as high flows recede.

In channels with a catchment area greater than 50 square miles, coherent jams appear unable to form as even the "key-debris" (whole mature trees) can be transported at the higher flows without becoming stuck in the channel. It appears, therefore, that there is a limiting catchment size (channel width) from which larger debris is made available to downstream areas. This has important management implications for controlling debris

at "run-of-the-river" structures such as bridges, locks and weirs and dams, because at-source debris management (riparian vegetation management) can be limited to channels above a basin given size.
It is evident from the thalweg plots that debris-filled reaches have far more irregular bed topographies than those which are completely debris-free. Therefore reaches, with their debris induced pools and shallows and abundant nutrient supply from the decomposing woody material, will offer a more diverse habitat for aquatic flora and fauna than debris-free uniform reaches (see Bilby & Likens, 1980). Localised bed scour around debris-jams appears to predominate where the sediment load is mainly sand grade or finer, while there appears to be more backwater and bar sedimentation around jams in reaches that have a gravel component to the sediment load.

Geomorphic field reconnaissance from the current research and previous studies (Wallerstein & Thorne, 1994) indicates that the impact of debris jams varies primarily with jam orientation relative to the main flow direction. Impacts change from depth adjustment through scouring in small creeks, to width adjustment through lateral erosion in medium size streams, to negligible effects in the largest creeks. Processes therefore appear to be watershed-scale dependant and field evidence suggests that the ratio of average riparian tree height (potential debris) to channel width can be used as an indicator of the likely impact that a jam will have on channel morphology and sediment routing.

A debris classification system, modified from Robinson and Beschta (1989), has been used to describe the observed geomorphic impact of debris jams throughout the drainage network. The progression of jam types is as follows:

Underflow jams: in small catchments where fallen trees span the channel at bankfull level. Local bed scour may occur under debris at high flows, otherwise the in-channel geomorphic impact of the LWD is minimal.

Dam jams: in channels which the average tree height to channel width ratio is rough equal to one, so that debris completely spans the channel cross-section. This type of jam causes significant local bank erosion and bed scour due to flow constriction, and backwater effects will cause sediment deposition in the lower energy environment upstream. Bars may also form immediately downstream of the jam.

Deflector jams: found where input debris does not quite span the channel so that flow is deflected against one or both of the banks causing localised bed scour and bank erosion. Subsequent bank failure results in the input of new LWD material to the reach so that the jam builds up further. Backwater sediment wedges and downstream bars may form at this type of jam provided that stream power is dissipated by the jam below the critical level for the bed load and suspended sediment transport.

Flow Parallel jams: found where channel width is significantly greater than the key-debris length, and flows are sufficiently competent to rotate debris so that it lies parallel to the flow. Debris is also transported downstream in high flows and deposited against the bank-base on the outside of meander bends or at channel obstructions such as engineering structures. Related bank erosion and bed scour will be minimal, and

bank toes may even be stabilised by debris build-up. Flow parallel debris may also initiate or accelerate the formation of mid-channel and lateral bars.

LWD MANAGEMENT PROGRAM

Relationships from the field data have been used to create a computer program that has been coded using C++. Input variables are riparian landuse type, average riparian vegetation height, channel width (determined from function of drainage area), and channel sediment type. The ratio of tree height to channel width is used to determine the debris jam type. The precise limits of each jam type have been determined from empirical and observational evidence from the survey sites. The magnitude of sediment retention and bed/bank scour at each jam is determined from the jam type and the D_{50} of the sediment present.

This model has been coupled with an GIS front end to demonstrate its potential use as a tool for integrated river basin management. The GIS has been created for the Abiaca Watershed, which is located within the DEC study area in northern Mississippi, and has a drainage basin area of about 150 square miles. This watershed was selected because it encloses four debris jam survey sites so that the model can be calibrated against actual field results. The program model outline is shown in Figure 1. The GIS has been created in the UNIX version of ARC INFO and comprises four layers; The drainage network (vector data); The road network: used to determine bridge locations (vector data); The landcover type: agricultural, open water or wooded (raster data); Soil type: used to determine primary channel sediment size (raster data); Digital terrain model: used to calculated drainage basin area (raster data). The GIS has been built with a tool bar so that layers can be displayed and analysis performed by simply pointing and clicking using the computer mouse. On-line help files are also included. Figure 2 shows a screen shot of the Abiaca Creek GIS displaying the drainage network, roads and landuse layer, the tool bar (top left) and a help text box.

To perform analysis using the GIS, for example to determine the best management strategy for woody debris at a particular bridge location, the following steps are taken. First zoom into the area of interest and use the mouse to mark the point of interest on the channel network. The GIS extracts the relevant values from its database for that location and passes then to an input file. The analysis program is then automatically activated and reads the input file, runs through the analysis process shown in Figure 2, and produces an output text file. The output file is then automatically read into the GIS and displayed on the screen. The output file displays the parameters that were selected, the calculated channel width, the expected geomorphic impact of LWD jams at the selected location, and the suggested debris management strategy with warnings about debris impacts at any structures in the reach. Figure 3 shows a screen shot of the GIS displaying a Debris Management Output file returned from the analysis program.

Figure 1 : LWD management program flow diagram

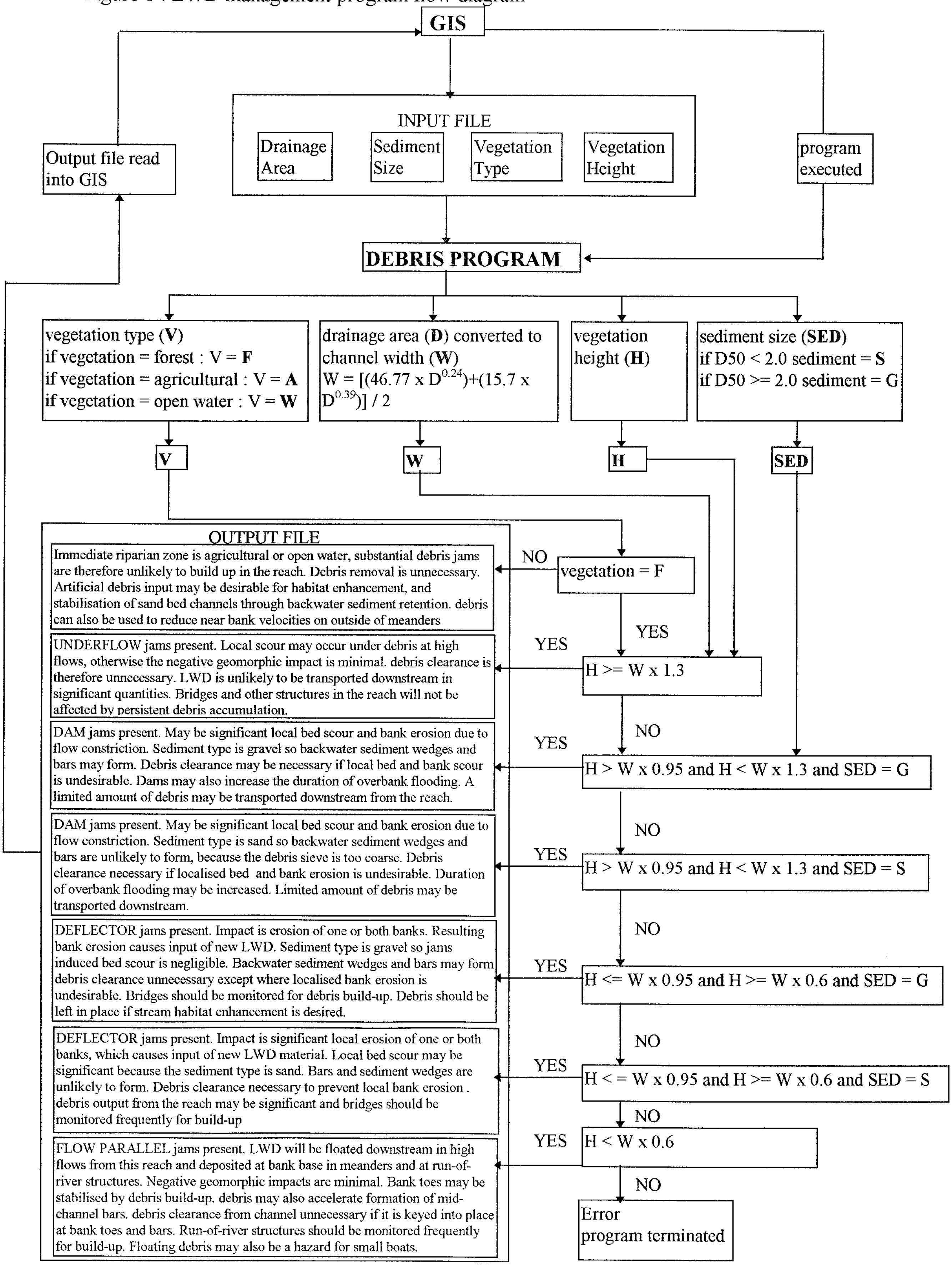


Figure 2. Abiaca Creek GIS showing watershed attribute layers and toolbar

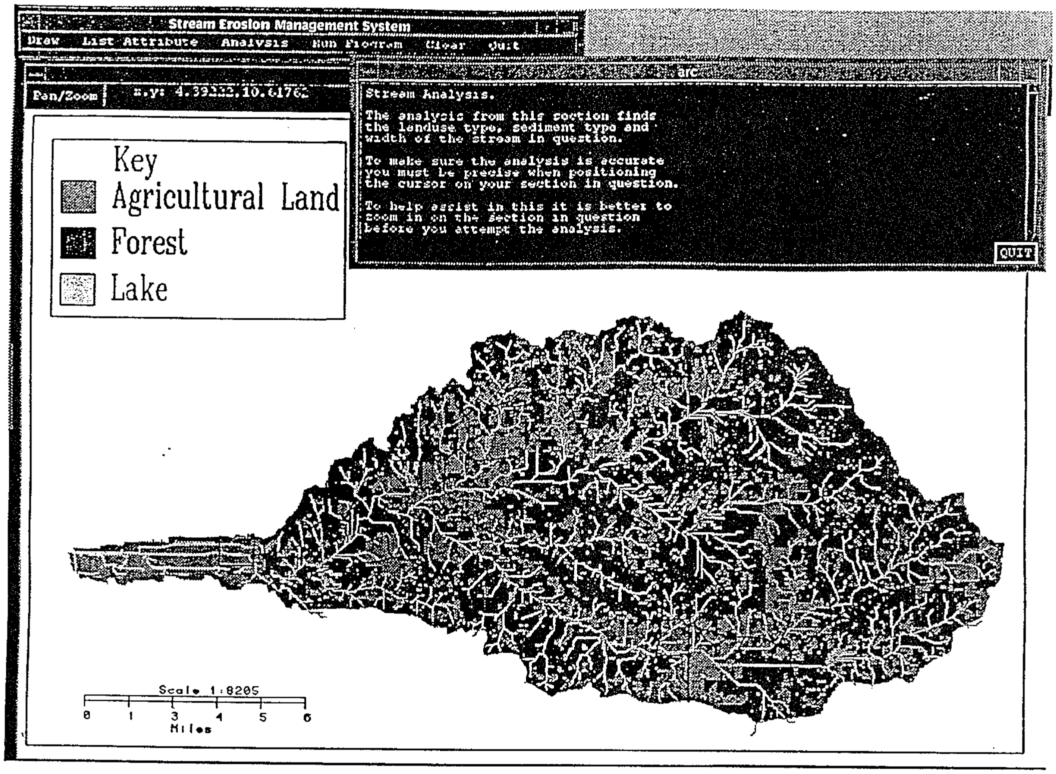
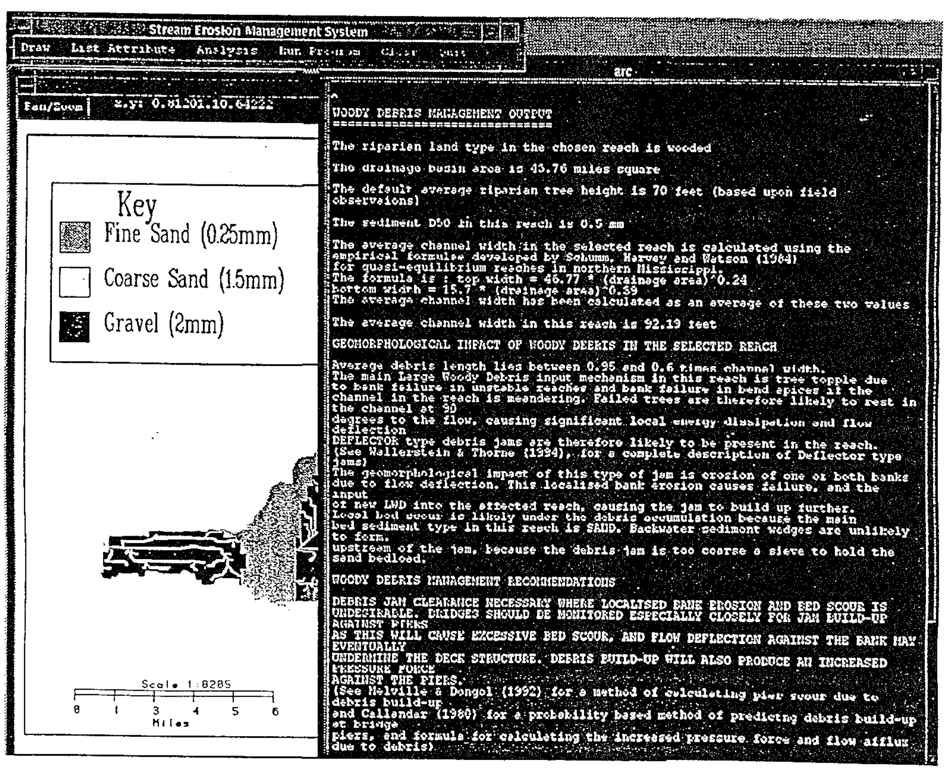


Figure 3. Abiaca Creek GIS showing debris management output



CONCLUSIONS

The impact of LWD varies spatially across the drainage basin, and is also dependant on channel stability sinuosity, riparian land type (debris availability), and channel sediment properties. Integrated basin management could be enhanced by using secondary GIS data and predictive programs such as the one discussed in this paper to provide preliminary information about channel geomorphic and hydraulic conditions for a large number of channel reaches. Site specific surveys could therefore be conducted in a more informed manner. Modifications will be made to this LWD analysis system to incorporate channel sinuosity, the degree of channel stability, and also the type of run-of-the-river structure encountered. The program will also take into account debris source and sink areas upstream of the selected site, so that estimates can be made of the potential volume of debris that could arrive at in-channel structures.

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